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# Vibration problem solution of high-capacity hydropower units

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**Abstract.** This paper proposes hydro generator vibration observations under various conditions and solution of a problem of high vibration in upper guide bearing of 110MW hydro generator. Among the test, which were carried out to identify vibration origin of hydro generating unit were: voltage drop tests, magnetic flux measurements, interferric gap measurements, turbine pressure pulsation measurements, etc. It was shown, that among other possible reasons, correct balancing, including pivot bearing adjustment was the most efficient measure to eliminate vibration in start-up modes of hydro power unit. According to the results of conducted step-by-step defect analysis, the corresponding recommendations were provided for service and maintenance regarding the generation unit No2 of Sangtuda-2 Hydro Power Plant, Tajikistan.

## 1. Introduction

Vibration monitoring system is the most powerful device for state tracking of rotating machines during their operation. Due to online monitoring of vibration and on basis of programmed routine attention, devastating failures of machine will be prevented.

Sangtuda-2 HPP unit's vibration system monitors relative and absolute vibration at three points: turbine guide bearing, thrust bearing and upper guide bearing.

To measure the absolute vibration in bearings, a displacement type of sensor is used due to the lowness of unit's speed (71.4 rpm). The type and characteristic of sensors represented below:

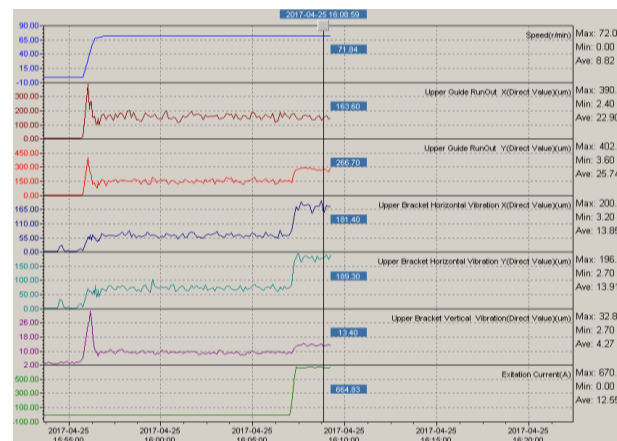
- Relative (run out) sensors:
  - measurement principle: eddy current;
  - frequency range: 0 – 10kHz(-3dB);
  - measuring range: 2mm;
  - sensitivity: -8mV/um(-200mV/mil).
- Absolute vibration sensor:
  - measurement principle: displacement;
  - frequency range: 0.5 – 150Hz(-3dB);
  - measuring range:  $\pm 1000\mu\text{m}$ ;
  - Sensitivity: 8V/mm $\pm 5\%$ .

## 2. Identification of the problem

During vibration monitoring of unit 2, vibration in pilot bearing raised and shut up to the alarm level, following which at some conditions an alarm signal was received. Vibration alarm was recorded by relative sensors, especially at Y-axes. Figure-1 illustrates condition of unit during startup, rolling and



standby modes. During the unit startup, relative vibration of X, Y axes and absolute vertical vibration raised, but horizontal vibrations (X and Y axes) maintain normal. This condition is the effect of unit's run, so when the unit reaches the rated speed (rolling mode fulfilled), the state of the unit becomes normal. After excitation system initiates (standby mode fulfilled), all conditions of vibration become worse.



**Figure 1.** Vibration characteristic at upper guide bearing.

### 2.1. Voltage drop test of rotor for ensuring equal impedances of poles

Vibration sensors check of their normal operation together with correct earthing of screen cable is higher at standby condition than during rolling. The main causes of higher vibration at standby mode can be disbalanced magnetic field in salient pole rotors. One of the causes of disbalanced magnetic field is short circuit in rotor's poles. To identify short circuits in rotor's poles, a rotor voltage drop test is used, that measures each pole's impedance. Test results showed in Table-1. They depict that impedances of poles are equal and are not short circuited in their standstill condition.

### 2.2. Measurement of magnetic flux to ensure accurateness of poles during rotating

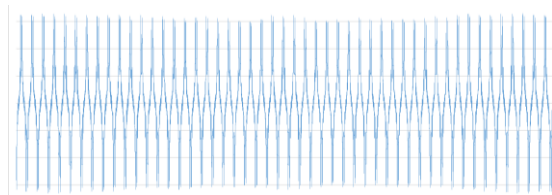
Although, voltage drop test is not comprehensive because of the rotor's rotation and the possibility of occurrence of short circuits only during its running due to the action of the centrifugal force on the rotor. For ensuring accuracy of poles during rotor's rotating, magnetic flux of poles is being monitored [1,2]. To measure the magnetic flux of poles, flow transducer is glued on stator core. Output of probe is being monitored and registered by capacity. Figures 2 and 3 illustrate induced voltage in flow transducer and calculated magnetic flux density at a holding mode of generator. Each of these graphs shows the symmetry values between pair poles that demonstrate the accuracy of poles.

**Table 1.** Voltage drop test with 2A ac current.

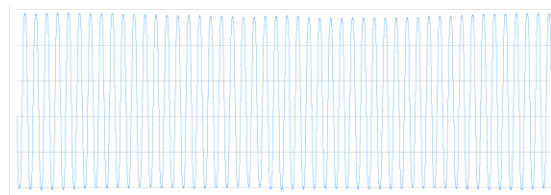
I=2,00 A    V <sub>total</sub> = 124,4 V								
Pole No.	Voltage (V)	Impedance (Ohm)	Pole No.	Voltage (V)	Impedance (Ohm)	Pole No.	Voltage (V)	Impedance (Ohm)
B1 – B82	1,432	0,716	B29 – B56	1,455	0,728	B57-B84	1,417	0,709
	-1,500	-0,750		-1,512	-0,756		-1,529	-0,765

### 2.3. Interferic gap measurement

Another cause of disbalanced magnetic field can be disharmony of the interferric gap between stator and rotor [3]. The result of measurement was compared with commissioning protocol that showed normal condition of the air gap between stator and rotor.



**Figure 2.** Induced voltage in probe at standby mode of generator.



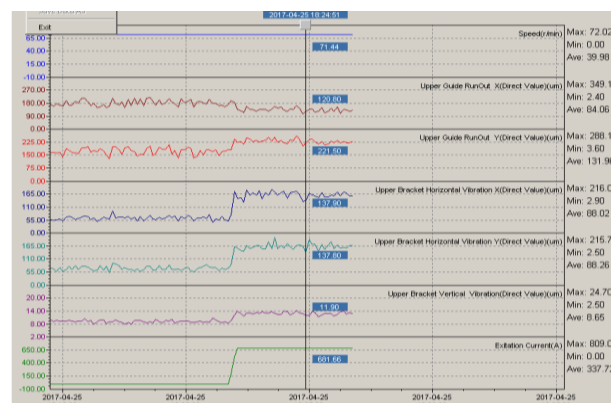
**Figure 3.** Magnetic flux density calculated from induced voltage at standby mode of generator

#### 2.4. Turbine pressure pulsation measurement

Study of rotor poles and interferric gap between stator and rotor showed that the state of interferric gap or rotor poles have not caused increasing of vibrations during the years, also vibration of the unit, especially upper guide bearing's vibration changed according to different conditions of power outturn and net head. After ensuring the operational capability of rotor poles and interferric gap, pressure pulsation data of turbine together with net head and blade angle was checked. Via this test, table of correlation between blade angle during the opening of wicket gates and net head that were used in turbine's operation system, was checked with optimum points. The optimum point for blade angle regarding to opening wicket gates and net head is the point in which correlation of vibration of the unit and pressure pulsation in turbine is optimum. This test showed that the table, used in system of regulation, does not differ from optimum point which leads to high vibrations.

#### 2.5. Balance weight installation in rotor

The next step to improve the vibration condition in upper guide bearing was to install the balance weight. After studying of FFT data of vibration in upper guide bearing by engineering department, balancing weight was installed in field spider. The result of installation of balancing weight is illustrated in Figure-4. These graphs show better condition than previously, but vibration is still higher than normal and sometimes depending on different conditions alarm level of relative vibration (run out) Y-axis is being received.



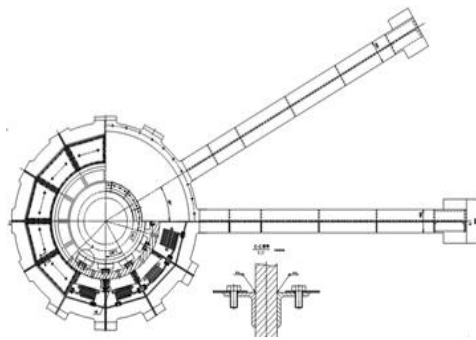
**Figure 4.** Magnetic flux density calculated from induced voltage at standby mode of generator.

#### 2.6. Adjustment of pilot bearing

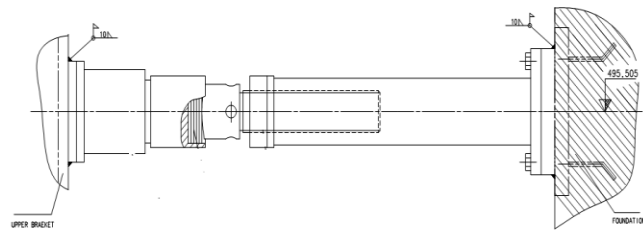
Secondly, after checking the vibration sensors, the adjustment of pilot bearing was made. Clearance between upper bearing's bush was checked by setting into operation. There were no differences that would lead to worse vibration conditions.

During the next annual routine attention of unit-2 (at 2018) pilot bearing was readjusted. Shoe clearance was adjusted to 0.17 mm. Due to this action vibration of the unit was brought to a better condition, but Y-axes relative vibration stayed high and close to the alarm level. This situation led to an overall check of mechanical joints of generators. Tightness of all bolts, nuts and latches of generator was checked.

During the check of upper bracket that has a damper in the end of each arm (Figures 5 and 6 illustrate upper bracket and jack), one of these joints was not adjusted and did not work normally.



**Figure 5.** Upper Guide bearing with bracket.



**Figure 6.** Upper bracket damper jack.

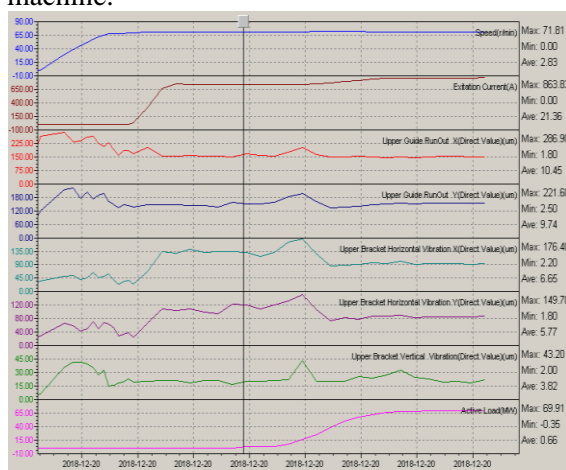
After damper jack was stripped down, then adjusted and put back in its position, unit is being started together with vibration check. The result of vibration records is illustrated in Figures 7 and 8. The graphs show that vibration value and disturbances decreased.

The value of vibration in Y-axis before adjustment of jack was about 250um when X-axes vibration was about 160um. After installation, the value of vibration in both axes is about 150-160um at standby mode. Vibration of the unit in other conditions (different powers and net heads) was also checked and problems were not detected.

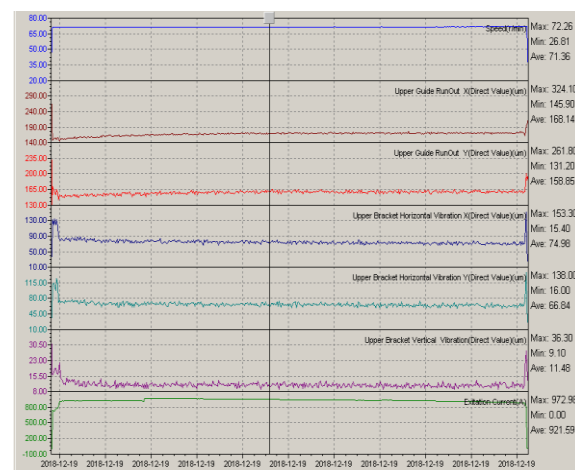
### 3. Conclusion

Accurate, correct and, of course, comprehensive maintenance leads to reliable work of equipment. Together with comprehensive routine attention, reliable work of equipment can be guaranteed.

On-line monitoring of vibration is a powerful device for detecting great majority of injuries of rotating machine.



**Figure 7.** Vibration graph after jack adjustment during start-up and loading.



**Figure 8.** Vibration graph after jack adjustment during start-up and 70 MW load.

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